What Happens When Food Marketers Require Restrictive Farming Practices?

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The dimensions of food quality that are valued by some consumers have expanded rapidly to include characteristics of the production process (e.g., usage of chemicals, sustainability, location, or confinement conditions of animals), marketing arrangements (in particular, their "fairness"), and implications of production and consumption of the product for the environment. The emergence of these new demands has been met by a variety of innovative market responses that have increased consumer choice. Small-scale agriculture has expanded in proximity to towns and cities to meet demands for locally grown foods. Niche producers and marketers have emerged to meet demands for free-range meat products and cage-free eggs. Since many of the emerging product traits are "credence attributes," a considerable literature has emerged concerning mechanisms for certifying the presence of such traits.

However, an alternative market response to emerging consumer interests in food products can have the effect of limiting consumer choice and increasing costs. This occurs when major restaurant chains, food-service operators, or grocery retailers limit the products they offer to consumers to those meeting certain characteristics with respect to the process utilized to produce the product, instead of offering a selection of products with alternative bundles of characteristics. Whereas intermediary buyers have long been involved in specifying the attributes of the products they seek to acquire, the emerging trend among key buyers is to seek a deeper involvement in agricultural production by specifying practices, traceability, environmental standards, animal-welfare requirements, and other "sustainability" criteria that their suppliers must meet. In these settings, producers and marketers may need to simultaneously meet multiple standards imposed by different buyers and/or third-party regulators.

This phenomenon has been studied much less frequently than the choice-expanding market responses mentioned earlier. Buyer restrictions on production practices to date are most common for animal products, including requiring cage-free eggs, and pork products produced without the use of gestation crates and with specific limits on the use of antibiotics. Burger King, Hyatt, and Sodexo have announced that they will sell only products made from cage-free eggs (The Humane Society of the United States 2013). The restaurant chain Chipotle now sells only pork that it claims is "all-natural," and antibiotic-free (Aubrey 2012). Fast-food giant McDonalds is contemplating similar standards for its suppliers. Grocery retailer Safeway is also embarking on a program to eliminate gestation crates in its pork supply chain (Cheeseman 2012).

Other production standards being considered by leading buyers include a ban on the use of antibiotics for growth promotion or disease prevention. A natural extension of the concept to plant products would have major buyers limiting purchases to crops raised without use of certain chemicals or genetic modifications or products produced from crops where farmers or farm laborers had received a specified treatment. Such actions by marketers may be motivated by demands by final-product consumers, but also seem to be inspired, at least in part, by external pressures from groups such as the Humane Society and notions of corporate responsibility.[1]

In this paper we examine the economic effects on producers and consumers of restrictions imposed by major intermediary buyers on production practices, and apply the

[1] One reason to make this inference is that organic production, the one dimension of "enhanced" product attributes where good public information is available, has made very modest inroads into animal agriculture, suggesting that, to date, such attributes are relatively unimportant to consumers.

analysis to proposed restrictions on pork production practices. These alternative production practices increase production costs, and whether quantitative estimates of the cost impact exist depends upon the particular input or practice at issue. The restrictions also increase costs for food processors and packers because they either require the intermediaries to engage in segregation practices in facilities that handle both restricted and unrestricted product or to dedicate facilities to each type of product, which increases costs in a variety of ways including for shipment of raw and processed product. We focus specifically on the prohibition by certain buyers of use of antibiotics for growth promotion and disease prevention, a practice wherein we have good information on cost-side impacts to both producers and processors.

Following a brief review of some relevant literature, we provide a conceptual overview of the key economic consideration at work when some buyers impose restrictive production conditions. We then construct a simple simulation model of the pork marketing chain and conduct simulation analysis to discern the impacts of a ban by key buyers on use of antibiotics for growth promotion and disease prevention.

Prior Work

Although no studies to date have examined the issues we describe within an analytical framework, considerable work has been undertaken to gauge consumers' willingness to pay for improved treatment of farm animals. Studies of animal welfare in Europe have tended to find a positive willingness to pay for improved standards of treatment but estimates have varied widely. Lagerkvist, Carlsson, and Viske (2006) found a 21% willingness-to-pay premium for chemical over surgical castration. When asked about a hypothetical tax on grocery bills to finance changes in the housing regime for hogs, consumers in Northern Ireland indicated willingness to pay ranging between £63−186 per year (Glass, Hutchinson, and Beattie 2005; Chilton, Burgess, and Hutchinson 2006).

Several surveys have estimated willingness to pay for generic labels indicating improved welfare or humane treatment of hogs, ranging between 10−43% (Hobbs 2003; Gracia, Loureiro, and Nayga 2011). Other surveys have indicated that consumers were willing to pay a premium of between 49−60% for pork produced without confining the sow to a gestation crate (Tonsor, Olynk, and Wolf 2009; Tonsor and Wolf 2011). For various improvements in housing conditions, including the size of pens, straw in pens, the number of hogs in a pen, and outdoor access, surveys have shown that consumers were willing to pay premia ranging from 3−194% (Liljenstolpe 2008; Olynk, Tonsor, and Wolf 2010).

Several studies have also estimated price premia for eggs produced using alternative technologies. Using scanner data, Chang, Lusk, and Norwood (2010) showed that cage-free eggs sell for a premium of 57% over conventional eggs, and organic eggs (which must be free range) sell for a premium of 85%. Using household scanner data, Andersen (2011) showed that Danish consumers paid a premium of 35% for organic or barn eggs, and 31% for free-range eggs.

The costs of adopting production techniques intended to enhance animal welfare have been studied less extensively but the available research suggests they can be significantly more than conventional methods. Relevant costs include one-time costs of switching to a new technology and differences between technologies in variable costs of operation. Sumner et al. (2011) estimated that farm costs were about 40% higher to produce eggs using an open-barn system rather than conventional cages. Based upon data from Buhr (2010), the additional farm cost of eliminating gestation stalls for sows is about $0.60 per cwt.

Conceptual Overview

Restrictive production practices when imposed by a downstream intermediary buyer necessarily increase farm production costs and also handling and processing costs due to costs of segregating items or having dedicated facilities. Let the demand share of intermediary buyers that requires a restrictive practice such as cage-free eggs or pork from hogs raised with restricted uses of antibiotics be denoted as δ. The remaining portion of the market demand does not require the restrictive production practice, and product produced according to the practice is afforded no premium if it is sold in this market segment.

A key facet of the problem is that, whereas the restrictive production practice and its associated cost applies to the entire animal, the share of the edible product utilized by buyers requiring the practice may be quite small. For example, major fast-food restaurants that require pork produced without use of gestation crates or with restricted uses of antibiotics may use only the portion of the edible hog used to produce bacon and breakfast sausage—about 15% of the weight of a live hog. The smaller is the share of the live hog used by these buyers, the larger the share of farm production that must be converted to the restrictive practice to meet a given demand share, δ, and the greater the price increase in equilibrium for product satisfying the restrictive practice.

To elicit production of product with the desired characteristics, the additional cost must be compensated entirely on the portion of the product purchased by buyers requiring the characteristics because the remaining production will be sold in the general market where it receives no premium. Under competition, costs cannot be shifted to segments of the market that do not require the restrictive practices because sellers who attempted to pass on higher costs in this manner would be undercut by competing sellers who did not participate in the restricted segment of the market. For example, processors who produced both conventional pork products and pork from hogs raised with restricted uses of antibiotics could not pass on increased costs in the form of higher prices to downstream conventional buyers because those prices would be undercut by competitors that sold only conventional product and, hence, had lower costs.

It is highly uncertain as to how restrictive production practices will impact demands for intermediary buyers imposing such requirements. Although, as noted, studies have found an incremental willingness to pay by consumers for products based on restricted on-farm treatment of animals compared to conventional treatments, most of these studies have relied upon hypothetical settings and surveys, making it unclear how well these results transfer to the marketplace. The few studies that have measured price premiums using scanner data have been in retail settings where the enhanced product is sold alongside conventional products and likely constitutes a very small share of sales within the product category.

These results may not provide much insight to the choice-restricting settings we model wherein a seller *only* offers product satisfying the restrictive production practice. In all cases the sellers requiring restrictive production practices are multiproduct sellers, i.e., restaurants, food service providers, or grocers for whom the animal product in question (for example pork from hogs raised with restricted uses of antibiotics) comprises a relatively small share of total sales revenue. Because the restrictive production practices raise costs, and those higher costs must be borne entirely on the portion of the product purchased by the intermediary, these products will sell at higher prices under most forms of single- or multi-product price competition.

In considering demand-side impacts for sellers who require restrictive animal production practices on products they purchase, the following factors are important: (i) regardless of whether the seller is a restaurant or a grocer, only a subset of the total population, *N*, of consumers patronizes that seller. Denote sellers by index j, and define $N_j \subset N$ as the subset of consumers who patronize seller j. Let each buyer $i \in N_j$ have demand $x_i(P_x, Z_i)$ for the animal product, *x*, under consideration and demand $y_i(P_y, V_i)$ for a second product sold by the seller, where *y* can represent a composite of the seller's other products. P denotes prices in these expressions, and Z_i and V_i represent demand-shift variables for consumer i that can include a seller's reputation or perceived "social responsibility." The demand-shift variables are subscripted to acknowledge consumer heterogeneity regarding how such factors impact individual demands. Let the number of consumers patronizing a seller be a function of the seller's prices and the demand-shift variables as well: $N_j(P_x^j, P_y^j Z, V)$, where superscript *j* denotes the prices charged by seller j, and *Z* and *V* denote the aggregation of demand-shift variables across consumers. We assume N_j is decreasing in the seller's prices.

There is no requirement that a consumer patronize only a single seller (i.e., "one stop shopping"), but we can assume that if a consumer does patronize a seller during a market period, she purchases her "market basket" (x_i, y_i) according to her demands. Thus, demand facing a seller j in a given period is

$$\sum_{i=1}^{N_j(\cdot)}[x_i\left(P_x^j, Z_i\right) + y_i(P_y^j, V_i)].$$

The preceding expression is useful in considering the ways requiring a restrictive production practice can impact demand and profit for a seller:

(i) P_x will rise due to higher costs for sellers requiring the restrictive practice under most models of single- or multi-product price competition. This represents movement along demand curves, x_i, and will reduce sales of *x* ceteris paribus.

(ii) Some consumers who do not value the enhanced attribute will cease to patronize the seller because of the price increase and N_j is decreasing in P_x^j ceteris paribus. This will reduce demand to the seller for both products *x* and *y*.

(iii) Existing consumers who value the enhanced product attribute will experience a shift in their *x* demand function and purchase more, ceteris paribus. They may also purchase more *y* because their perception of the "quality" of the seller is enhanced.

(iv) Consumers who value the enhanced attribute but heretofore did not patronize seller *j* choose to patronize *j* due to the presence of the enhanced attribute. This increases demand facing the seller for both *x* and *y*.

Profit maximizing sellers will elect to require the restrictive production practice if the net effect of these demand-side impacts is sufficient to outweigh the higher costs that the seller will incur in purchasing product *x* containing the restricted characteristic. One immediate implication of this demand decomposition is that profit-maximizing sellers may require the restrictive production practice even if it causes a net decrease in sales of product *x* because the profit margin on *x* sales that are made may be higher and sales and profit margin for other product(s) *y* may increase if the action enhances the seller's reputation among some consumers. Thus, restrictive production practices imposed by profit-maximizing restaurant chains, grocers, and food-service operators may reduce profits in the farm and processing sectors.

The Simulation Model

To examine quantitative impacts from selected buyers imposing restrictive production practices we construct a fixed-proportions model of a vertical competitive market for hogs and pork products.[2] We begin with a linear farm supply function for live hogs, and a linear aggregate consumer demand function for pork products. In conducting simulations we calibrate the model around base year 2011.

- Farm (primary) supply: We fit a linear supply function through base year domestic production and farm price for live hogs and assume a base price elasticity of supply that holds at the 2011 equilibrium point. Primary supply is $Pf^S = a + bQf^S$. Here *f* represents values at the farm level, P denotes price, Q denotes quantity, and S denotes a supply relationship. We then solve for the intercept, a, and slope parameter, b, of the supply function such that the function fits the 2011 equilibrium values and has the base supply elasticity given those values.

[2] Because the buyers implementing the restrictive practices are often market leaders such as McDonalds, it may be reasonable in extensions to this work to incorporate both buyer and seller market power exercised by intermediaries into the analysis.

- Derived (retail) supply: Final product supply is derived from farm supply by applying the raw-to-processed product conversion ratio and adding the processing/marketing costs, *c*, on a per-unit basis: $Pr^S = \frac{Pf^S}{\alpha} + c$. We assume c is measured in terms of finished-product units. The farm to-retail product conversion is $Qr^S = Qf^S \cdot \alpha$ where $\alpha \approx 0.74$ for pork. Derived supply is thus the linear function:

$$Pr^S = \left(\frac{Pf^S}{\alpha}\right) + c = \frac{a + bQf^S}{\alpha} + c = \frac{a + b\left(\frac{Qr^S}{\alpha}\right)}{\alpha} + c = \left[\left(\frac{a}{\alpha}\right) + c\right] + \frac{b}{\alpha^2}Qr^S.$$

- Retail (primary) demand: We also assume an aggregate linear consumer demand elasticity for pork products, $Pr^D = \gamma - \beta Qr^D$, where *r* denotes variables that apply at the retail or consumer level, and the *D* superscript denotes a demand relationship. We solve for the intercept and slope coefficients of the demand function such that the function goes through the base year values for disappearance and price and has the base demand price elasticity at that point.

- Derived (farm) demand: Derived demand consists of primary demand, adjusted for raw-to-processed conversion, less all processing and marketing costs per unit. We use a similar process to convert primary demand to derived demand at the farm level as was used to convert primary supply to derived supply:

  $Pf^D = (Pr^D - c) \cdot \alpha,$ or

$$Pf^D = (Pr^D - c) \cdot \alpha = (\gamma - \beta Qr^D - c) \cdot \alpha = (\gamma - \beta(Qf^D \cdot \alpha) - c) \cdot \alpha$$
$$= (\gamma - c)\alpha - \alpha^2 \beta Qf^D.$$

Model equilibrium conditions are the following:

$$Qf^S = Qf^D = Qf^*$$
$$Pf^S = Pf^D = a + bQf^* = (\gamma - c)\alpha - \alpha^2\beta Qf^*$$
$$Qr^S = \alpha Qf^S$$
$$Qr^D = Qr^S = Qr^*$$
$$Pr^D = Pr^S = \gamma - \beta Qr^* = [(a/\alpha) + c] + \frac{b}{\alpha^2} Qr^*.$$

Equilibrium consists of market clearing in both the farm and retail markets and farm and retail prices determined from the farm supply and consumer demand functions, respectively, given the market-clearing quantities.

Private-Buyer Policies to Regulate Pork Production Practices

We calibrate the model described in the prior section and utilize it to evaluate impacts under alternative plausible conditions when key intermediary buyers prohibit use of antibiotics for growth promotion and disease prevention in pork products they purchase. We use an antibiotic ban because it is a topical issue under consideration for several major buyers and is a practice for which we have good estimates of production and processing cost impacts.

We consider three subcases. In subcase 1 consumers overall do not change the quantity of pork they would buy at any given price. Under subcase 2 consumer demand increases for sellers of pork free of the use of antibiotics for growth promotion or disease prevention (AF) pork, because it is a desirable attribute in the eyes of some consumers, but there is no change in demand among sellers of conventional pork. In subcase 3, the increase in demand for AF pork is matched by a commensurate reduction in demand for conventional pork. This would represent the case where some buyers switch their patronage to AF pork sellers from other sellers.

Subcase 1 involves shift in primary supply due to higher costs of producing pork that is antibiotic free. We model this as an increase in cost per unit for both producers and processors, and the required data to implement the simulation are the incremental production costs due to inability to use antibiotics (other than to treat observed disease) and processing costs due to segregation, certification, etc. Denote the incremental farm costs per unit as Δcf. The intercept on the linear farm supply function thus shifts to $\mathrm{a} + \Delta\mathrm{cf}$. The incremental unit costs incurred by processors and other intermediaries (accounting for farm-to-retail conversion) due to segregation, certification, testing, etc. are denoted as Δcr.

In subcase 2 we incorporate a demand shift in the AF segment of the market, and the market equilibrium responds to a shift in both functions. We treat a demand shift as proportional. This involves rotating the inverse demand function out and maintaining the intercept, γ. Because there is no objective information available on the magnitude of any demand shift, we use current market shares for organic pork, eggs, and dairy to illustrate plausible demand-shift impacts. They indicate the share of the market for some alternative products that have health-related claims and attract some of the same customers that would be naturally be attracted to AF pork and, thus, may suffice to set a range of magnitudes for plausible demand shifts. These shares are, respectively, 0.02%, 1.47%, and 2.7%.[3] Subcase 3 then involves contracting the demand in the conventional

[3] Current market shares are not the same as demand shares or demand shifts due to availability of a new or relatively new product. The current prices of organic products are high and their market shares are reduced relative to what they would be at lower relative prices. Nonetheless these proxy values for the demand shift are a starting point for the analysis.

market by an amount equivalent (after accounting for different sizes of the two markets) to the demand increase in the AF segment of the market.

Buyers who require AF pork have a collective demand that represents a fraction $\delta > 0$ of final consumer demand. All other intermediary buyers do not distinguish between AF and conventional pork, and these buyers incur no incremental cost at the retail or food service level. As noted, the buyers who demand AF pork utilize only a portion of the edible portion of the hog, despite the fact that the entire hog is raised AF. Denote the portion used by a given buyer j as $\theta_j < 1$. This fact implies that in general more than δ percent of farm production must convert to AF production to supply the products being demanded by AF buyers. For example, suppose that AF buyers consisted mainly of restaurants that demanded only bacon and breakfast sausage, meaning the remaining edible products from the AF hogs would be sold in the conventional market and earn no premium.

A limiting case is when the share of the market that must convert to producing AF pork is δ/θ^{min}, where $\theta^{min} = \min\{\theta_1, \theta_2, \ldots, \theta_j\}$. In other words, among j buyers demanding AF pork, θ^{min} represents the portion required by the buyer using the least amount of the edible hog. This case would occur when all AF buyers required the same portions of the edible hog (even if some buyers demanded additional portions) and prices in the AF and conventional segments were the same so that the demand share of AF pork, δ and the quantity share, $Q^{AF}/(Q^{AF} + Q^N)$ were identical, where *N* denotes conventional or "*N*on AF" pork. In reality the portion of hog production that must convert to AF will be less than δ/θ^{min} because price will increase in equilibrium for AF products, relative to N products, due to the former's higher costs. The portion of production that must convert will also be less if the buyers demanding AF pork use different cuts, e.g., some require bacon and sausage only, while others require ribs and chops only. However, the important general principle remains that a greater portion of hog production must convert to meet the restrictive practice than can be sold in that segment of the market. In what follows we will simply use θ to denote the relevant portion of the hog utilized by AF buyers.

On the supply side we assume that production can shift relatively seamlessly between producing N pork and AF pork. There is, in essence, one hog supply function and each supplier can produce AF or N hogs; AF and N hogs are perfect substitutes in supply. Thus, the market can supply N pork according to the inverse supply (aggregate marginal cost) function

$$Pf^{S-N} = a + b(Qf^{S-N} + Qf^{S-AF})$$

and can produce AF pork according to the function

$$Pf^{S-AF} = a + \Delta cf + b(Qf^{S-AF} + Qf^{S-N}),$$

Writing the functions in this way incorporates that the opportunity cost of supplying AF pork is the foregone opportunity to supply N pork, and the marginal cost of producing each type is determined by the total production of the two types.

We derive a total supply to retail of AF pork and then recognize that only θ share of that AF pork contains products that AF buyers demand. We assume that these incremental costs are borne entirely by AF products.

The farm-to-processed-product conversion ratios are unchanged: $Qr^{S-i} = Qf^{S-i} \cdot \alpha, i = AF, N$.

$Pr^{S-AF} = (Pf^{S-AF}/\alpha) + c + \Delta cr$

Now substitute for Pf^{S-AF} in the preceding expression using the AF farm supply equation:

$$Pr^{S-AF} = \frac{1}{\alpha}[a + \Delta cf + b(Qf^{S-AF} + Qf^{S-N})] + c + \Delta cr$$

$$Pr^{S-AF} = \frac{1}{\alpha}\left[a + \Delta cf + \frac{b}{\alpha}(Qr^{S-AF} + Qr^{S-N})\right] + c + \Delta cr.$$

Substituting the expression for Pr^{S-N}into the preceding equation and simplifying yields:

$$Pr^{S-AF} = \frac{Pf^{S-N}}{\alpha} + \frac{Pf^{S-AF} - Pf^{S-N}}{\alpha\theta} + c + \frac{\Delta cr}{\theta}$$

This equation indicates that to supply AF pork, processors must receive a price great enough to compensate farmers for the necessary premium to induce them to supply AF hogs and for the processors' additional segregation and related costs for handling AF pork, reflecting that not all of the AF pork will be sold in the AF market and earn a price premium. Now substitute for Pf^{S-AF} and Pf^{S-N} using the supply equations identified previously:

$$Pr^{S-AF} = \frac{1}{\alpha}\left[a + \frac{\Delta cf}{\theta^2} + b\left(Qf^{S-AF} + Qf^{S-N}\right)\right] + c + \frac{\Delta cr}{\theta}$$

and then convert quantities at the farm to quantities at retail/food service:

$$Pr^{S-AF} = \frac{1}{\alpha}\left[a + \frac{\Delta cf}{\theta^2} + \frac{b}{\alpha(Qr^{S-AF} + Qr^{S-N})}\right] + c + \frac{\Delta cr}{\theta}.$$

This expression written in quantity-dependent form is:

$$Qr^{S-AF} = -\frac{\alpha}{b}[(a + \Delta cf) + \alpha(c + \Delta cr)] + \frac{\alpha^2}{b}(Pr^{S-N} + \frac{\Delta cf}{\alpha} + r) - Qr^{S-N}$$

This equation is the total direct supply function of AF pork to the market, accounting for the supply of N pork to the consumer market. We now must recognize that only θ portion of this amount consists of supply that the AF demanders will use, and the rest must flow into the N market where it will not be separately identified and thus can receive no premium. We denote the supply of AF pork to the AF market as $Qr^{S\text{-}AF\rightarrow AF} = \theta Qr^{S\text{-}AF}$ and the supply of AF pork that goes to the N market as $Qr^{S\text{-}AF\rightarrow N} = (1\text{-}\theta)Qr^{S\text{-}AF}$.

Derived supply of N hogs to the N pork market is found in an identical manner:

$$Pr^{S-N} = \left(\frac{Pf^{S-N}}{\alpha}\right) + c$$

$$Pr^{S-N} = \frac{1}{\alpha}\left[a + \frac{b}{\alpha}(Qr^{S-AF} + Qr^{S-N})\right] + c$$

$$Qr^{S\text{-}N} = -\frac{\alpha}{b}(a + \alpha c) + \frac{\alpha^2}{b}Pr^{S\text{-}N}\text{-}Qr^{S\text{-}AF}.$$

Total supply of pork to the N consumer market consists of all of the pork produced from N hogs, plus the portion of the AF supply that is directed to the N market.

In equilibrium production will enter AF pork and exit regular pork production until the return is the same regardless of which pork type is produced. This differential return, however, must reflect the fact that AF pork producers and processers will not be able to sell their entire product in the AF market because AF buyers purchase only certain cuts. Thus, we must have in equilibrium in the farm-sector market:

$$\theta Pf^{S-AF*} + (1-\theta)Pf^{S-N*} = Pf^{S-N*} + \Delta cf \longrightarrow Pf^{S-AF*} = Pf^{S-N*} + \Delta cf/\theta$$

A similar condition must hold for the consumer market:

$$\theta Pr^{S-AF*} + (1-\theta)Pr^{S-N*} = Pr^{S-N*} + \left(\frac{\Delta cf}{\alpha}\right) + \Delta cr \longrightarrow$$

$$Pr^{S-AF*} = Pr^{S-N*} + (\Delta cf/\alpha\theta) + \Delta cr/\theta.$$

Demand is decomposed according to $Qr^D = Qr^{D-AF} + Qr^{D-N}$, where

$$Qr^{D-AF} = \delta Qr^D = \frac{\delta(\gamma - Pr^{D-AF})}{\beta}$$

$$Qr^{D-N} = (1-\delta)Qr^D = \frac{(1-\delta)(\gamma - Pr^{D-AF})}{\beta}.$$

The equilibrium conditions are as follows for the consumer market:

$Qr^{D\text{-}AF} = Qr^{S\text{-}AF \rightarrow AF}$, equilibrium in the AF market;

$Qr^{D\text{-}N} = Qr^{S\text{-}N} + Qr^{S\text{-}AF \rightarrow N}$, equilibrium in the N market;

$Qr^{D-N} + Qr^{D-AF} = Qr^{S-N} + Qr^{S-AF}$, market clearing condition for all pork; and

$Pr^{S\text{-}AF*} = Pr^{S\text{-}N*} + (\Delta cf/\alpha\theta) + \Delta cr/\theta$, AF and N market arbitrage condition.

Unknowns in the four-equation system are the equilibrium values of retail prices and quantities in the N and AF markets.

A parallel set of conditions can be derived to express equilibrium in the farm market. Inverse (price dependent) primary (retail) demand for AF pork is:

$$Pr^{D\text{-}AF} = \gamma - \frac{\beta}{\delta} Qr^{D\text{-}AF}.$$

To write the derived (farm) demand for AF pork in the form of hogs, we must account for (i) conversion, (ii) processor/retailer unit costs, and (iii) the fact that a total weight of AF hogs must be produced in excess of weight of AF pork demanded (accounting for conversion) because AF buyers demand only certain parts of the hog. Thus, the following relationship holds:

$$Pf^{D-AF} = (Pr^{D-AF} - c - \Delta cr)\alpha\theta + (Pr^{D-N} - c)\alpha(1-\theta).$$

Next we substitute for the retail prices and substitute the farm-level quantities in place of the retail quantities:

$$\mathrm{Pf}^{\text{D-AF}} = \left[\gamma\text{-c-}\Delta\text{cr-}\frac{\beta\alpha}{\gamma}\mathrm{Qf}^{\text{D-AF}}\right]\alpha\theta + \left[\gamma\text{-c-}\frac{\beta\alpha}{(1\text{-}\delta)}\mathrm{Qf}^{\text{D-N}}\right]\alpha(1\text{-}\theta).$$

This expression is the inverse derived demand for AF hogs at the farm level. We can rewrite this relationship in direct form by solving for Qf^{D-AF}:

$$Qf^{D-AF} = \frac{\delta}{\beta\alpha}\left(\gamma - c - \Delta cr - \frac{1-\theta}{\theta}(\gamma - c)\right) - \frac{\delta}{\beta\alpha^2\theta}Pf^{D-AF} - \frac{(1-\theta)\delta}{(1-\delta)\theta}Qf^{D-N}.$$

Given the linear base functions, the direct derived demand for AF pork at the farm is a linear function of Pf^{D-AF} and Qf^{D-N}, where the dependency on Qf^{D-N} reflects the dependence of the AF market on the N market because some parts of the AF hogs must be sold as N product in the N market.

Inverse primary demand for N pork is:

$$Pr^{D-N} = \gamma - \frac{\beta}{(1-\delta)}Qr^{D-N}.$$

To convert this demand to farm level also requires accounting for (i) processing/retail unit costs, (ii) conversion of the units, and (iii) the fact that some pork will be supplied to the N market through AF hogs.

We handle (i) and (ii) in the usual way: $Pf^{D-N} = (Pr^{D-N} - c)\alpha$.

Use the consumer demand function to substitute for Pr^{D-N} and the quantity conversion ratio to introduce farm-level (live hog) units:

$$Pf^{D\text{-}N} = \left[\gamma\text{-}\frac{\beta}{(1\text{-}\delta)}Qr^{D\text{-}N}\text{-}c\right]\alpha = \left[\gamma\text{-}\frac{\beta\alpha}{(1\text{-}\delta)}Qf^{D\text{-}N}\text{-}c\right]\alpha.$$

Hogs for the N market will be supplied from two sources—hogs produced using antibiotics and hogs produced AF, but from whom parts must be sold in the N market. We introduce parallel notation from the consumer market model to reflect this situation:

$$Qf^{D\text{-}N} = Qf^{D\text{-}N\rightarrow N} + (1\text{-}\theta)Qf^{D\text{-}AF}.$$

$$Pf^{D-N} = \left[\gamma - c - \frac{\beta\alpha}{(1-\delta)}(Qf^{D-N\rightarrow N} + (1-\theta)Qf^{D-AF})\right]\alpha$$

Finally we solve for farm-level N demand in its direct form:

$$Qf^{D\text{-}N\rightarrow N} = \frac{1\text{-}\delta}{\beta\alpha}(\gamma\text{-}c)\text{-}\frac{1\text{-}\delta}{\beta\alpha^2}Pf^{D\text{-}N}\text{-}(1\text{-}\theta)Qf^{D\text{-}AF}.$$

Farm market equilibrium conditions are as follows:

$Qf^{D-AF} = Qf^{S-AF}$, equilibrium in AF hog market;

$Qf^{D\text{-}N\rightarrow N} = Qf^{S\text{-}N}$ equilibrium in the N hog market, taking account that a portion of the supply comes from AF hogs;

$Qf^{S-AF} = Qf^{D-N} + Qf^{D-AF}$, market-clearing for all hogs; and

$Pf^{S-AF} = Pf^{S-N} + \frac{\Delta cf}{\theta}$, farm-level AF and N supply arbitrage condition.

Model Calibration

The model is calibrated around 2011 values for U.S. hog production and domestic consumption of pork products. Imports of hogs from Canada and U.S. exports and imports of pork products are also incorporated at 2011 values.[4] We constructed a linear supply function for hogs by assuming an intermediate-run price elasticity of pork supply of 1.8 from Lemieux and Wohlgenant (1989). We calibrate the linear function so that it reproduces 2011 values for domestic production and farm price, given this base elasticity. Total domestic demand for pork products was calibrated in a similar manner. We utilized a price elasticity of domestic consumer demand for pork of -0.68 (Okrent and Alston 2011) and then calibrated a linear demand function to reproduce the 2011 price and consumption data.

Our consumer demand elasticity compares very closely to values of -0.69 and -0.79 used by Buhr (2005), but Buhr used much lower values for the price elasticity of hog supply. Buhr's supply elasticities of 0.4 and 0.22 may apply in the very short run. However, because pork uses only a relatively small portion of the available grain and oilseeds available (meaning that these inputs are likely in very elastic supply to the industry) and facilities can be built or removed given time for adjustment, the relatively elastic supply response estimated by Lemieux and Wohlgenant is more reflective of the intermediate-run horizon that is relevant for this study as we consider industry adjustment to buyers requiring restrictive production practices.

For the sake of parsimony in formal model construction and consistency with available data upon which the model is calibrated, we aggregated all processing and

[4] For parsimony of the model, we incorporate trade volumes as fixed, exogenous amounts. We then can alter trade volumes in response to alternative scenarios considered in the simulation as a comparative statics exercise.

marketing activities into a single sector that is assumed to operate competitively with constant unit cost. The difference between 2011 average retail price for pork products and 2011 average farm price (each measured in terms of carcass weight per cwt.) was used to represent the total costs (including return on investment) incurred by processors, marketers, food service firms, etc. in converting live hogs to pork products for consumption. Given the farm-level supply of hogs, the derived supply of pork products to consumers was obtained by adding the aggregate per-unit costs for processing and marketing to the farm supply. Similarly, the derived demand at the farm level for live hogs was found by subtracting the per-unit marketing costs from the primary consumer demand function. Equilibrium farm and consumer prices and quantities of production and consumption in the base model were then found by equating supply and demand in both the farm and consumer segments of the market.

Incremental Production and Processing Costs to Produce AF Pork

Cromwell (2002) summarizes the main biological and economic effects of antibiotic use for growth promotion and disease prevention in hog production from an animal science perspective. He notes significant increase in the weight gain per unit of feed from about seven percent for young pigs to about 2 percent for larger hogs between 24 and 89 kg. He also notes gains in farrowing rate and pigs per litter. His summary of effects on cost yields "very conservative" estimates of about $3 per pig. This does not include savings from antibiotic use in the breeding herd from better farrowing rates and pigs per sow that yield additional reduced costs of about $1 per pig. The conservative total therefore is about $4 per pig.

Pork producers in those countries that have discontinued the use of antibiotics for growth promotion and disease prevention reported feed efficiency reductions and increases in mortality and necessary cull. Using data from Sweden and Denmark, several studies have estimated the cost of banning such use of antibiotics in pork production in the United States. Based on the experiences of pork producers in Sweden, Hayes et al. (2001) examined the likely effects of disuse of antibiotics for growth promotion and disease prevention on farm practices and growth performance, including mortality, pigs per sow, feed efficiency, and veterinary and therapeutic costs under U.S. conditions. The veterinary and therapeutic costs (net of feed-grade antibiotics costs) increased by $0.25 per head. In the most-likely case scenarios, the age of piglets at weaning would increase; the growth time and feed efficiency would worsen; and the number of piglets per sow would decrease by up to 5%. Additionally in the most likely scenario, fattening–finish mortality would increase slightly. For the most likely scenario Hayes et al. (2001) estimated an additional cost *per head* of $6.05 in the first year and $5.24 per head after all adjustments had been completed by year 10. The year-10 estimate translates into about $2.00 per cwt. live weight. Based on the Danish experience Hayes and Jensen (2003) estimated slightly lower costs. They also note additional capital costs for addition barn space would be required.

Using cost data from pork producers in Iowa, Larson and Kliebenstein (2003) compared costs of production system without use of antibiotics for growth promotion and disease prevention to the conventional system. They found about $2.35 higher costs per hog in annual facilities costs for the AF system and additional cost differences of $3.04 for a total of $5.39 per head or $2.16 per cwt. live weight. Based on losses in feed efficiency and increases in discounted market prices for underweight hogs, Brorsen et al. (2002) estimated the total cost of production using the restricted (AF) system to be $2.76 per hog higher than the conventional system.

A more recent study using data from commercial sized operations over 15 months from June 2006 to August 2007 was conducted at Iowa State University. The trials compared systems with and without use of antibiotics for growth promotion and disease prevention with each system optimized for the regime in place. This study discussed by veterinary professor Roger Main found that most of the additional mortality and feed efficiency deficits occurred in the smaller pigs. Total additional costs "from birth to market" for the AF system were $4.40 per cwt. live weight, somewhat higher than the more hypothetical studies completed earlier in the decade.

The range of estimates is spanned by Brorsen et al. and the recently reported 2006-2007 Iowa State study. All these studies were conducted before the higher feed prices that occurred in 2007 and 2008, which have continued through 2012 and are projected to continue for the next several years at least. With more expensive feed the importance of losses in feed efficiency are magnified. We use a range of between $5 per head and $8 per head, which adjusts estimates upward for inflation and especially the jump in feed prices, given the importance of feed efficiency in the differential. The lower end of the range is somewhat higher than the lowest estimates in the literature and the higher end of the range is well below the high estimate of about $12.10 per head estimated by Main and colleagues at Iowa State.

As to incremental processing costs associated with production of AF pork, large-scale hog slaughter and processing facilities serve a variety of buyers, and they will need to segregate AF hogs from the conventionally raised hogs. In addition they must conduct testing to insure pork is from hogs raised without the use of antibiotics for growth promotion and disease prevention, and establish traceability and assurance systems. To estimate the magnitude of these costs we relied upon a study conducted by Informa Economics (2010) regarding segregation costs incurred by hog processors in complying with country-of-origin-labeling (COOL). The costs will be similar in our view because, in each instance, they are associated with the requirement that processors separate animals with different characteristics and certify that the product sold complies with the indicated characteristic (e.g., U.S. origin or raised AF). Based upon the Informa study, we estimate the additional costs for processing and marketing the restricted pork to be $4.00/cwt carcass weight.

The alternative to incurring these segregation costs would be to use dedicated facilities that slaughtered only AF hogs and supplied only the pork from those animals. We expect that transport costs for hogs and pork and loss of scale economies would make such operations more costly than the segregation costs.

Simulation Results

Results of the simulation analysis for subcase 1 (no demand shifts) are summarized in tables 1 (impacts on prices) and 2 (impacts on production and consumption). In all cases, the incremental costs for producing pork from AF hogs are set at the midrange value of $3.15 per cwt. carcass weight for hog production and $4.00 per cwt. carcass weight for processing and distribution. The top third of both tables examines the case when $\delta = 0.1$, i.e., 10% of the market demand requires restricted pork, the middle portion examines a

$\delta = 0.2$ demand scenario, and the bottom third examines a high-demand scenario, where 30% of the market requires restricted pork. Each portion of the table considers three alternative values for θ, the relevant portion of the AF hog utilized by buyers demanding restricted pork—low, medium, and high portions of 30%, 40%, and 50%, respectively. All simulations are evaluated relative to the market baseline equilibrium contained at the top of each table, where there is a single market for conventional pork.

The simulation results demonstrate the importance of the value of θ in influencing the market equilibrium in the presence of buyers who require pork from hogs with no use of antibiotics for growth promotion or disease prevention. If some buyers utilize a relatively small portion of the products from hogs raised and processed with the restricted practices and all buyers use those same cuts even if other buyers demand a greater portion of the finished hog, then the price premium for these hogs sold into the restricted market segment must be high enough to compensate for the higher costs incurred producing and processing the entire hog. This scenario would tend to represent the situation where AF buyers were mainly restaurant chains or food-service operators. In the low-θ scenario, regardless of the total share of the market that is requiring AF pork, products sold and marketed to consumers as meeting the restriction that no antibiotics were used for growth promotion and disease prevention must sell for about a 19% premium over conventional pork products. Similarly, the farm price (carcass weight) for hogs raised under the restriction must be about 12% higher than the price for a conventional hog. As θ increases, reflecting that buyers of pork produced under the restriction are utilizing more of the hog, the required premium is less.

A second key result to note is that buyers of pork produced under the restriction exert a disproportionate influence on the hog market, once again due to the reality that these buyers will only utilize a portion of the products produced from each hog. Consider for example, the scenario where 30% of total pork demand comes from such buyers, but the relevant θ for those buyers is 0.3, reflecting a common use of only a relatively small edible portion of the hog. In this case about 90% of hog production would have to be raised AF in order to provide the 30% demand share required by these buyers.[5]

Under all of the scenarios simulated in tables 1 and 2, the total production and sale of pork products decreases. This result follows simply as a consequence that a significant segment of the market (determined in the simulation by the value of δ) requires a more expensive pork product. These higher production and processing costs cause an increase in the consumer price relative to conventional pork products and, thus, lower production and sales in equilibrium. The effect is greater the larger the share of the total production that is raised under the restriction (as determined jointly by the values of δ and θ). The impact on production ranges from a decrease of only 0.5% when $\delta = 0.1$ and $\theta = 0.5$ (i.e., buyers of pork produced under the restriction are a small share of the market and utilize a relatively large portion of each hog) to a decrease of 3.3% when $\delta = 0.3$ and $\theta = 0.3$ (i.e., buyers of pork raised under the restriction are a large share of the market, but utilize a relatively small fraction of each hog).

All hog producers are made worse off in all the scenarios simulated. Although hog producers who convert to making no use of antibiotics for growth promotion and disease prevention are compensated for their additional costs, the farm price for hogs

[5] The quantity share for AF pork is less than its demand share due to price effects, as discussed previously.

declines as a consequence of declining sales for pork products and, hence, for live hogs also, due to higher consumer prices in the restricted segment of the market. The reduction in farm price ranges from only 0.25% or $0.22 per cwt. carcass weight ($\delta = 0.1$ and $\theta = 0.5$) to 1.81% or $1.59 per cwt. carcass weight ($\delta = 0.3$ and $\theta = 0.3$). The overall revenue loss to hog producers, reflecting both reduced sales and lower prices, ranges from $144 million to just over $1 billion.

In subcase 1, there is no overall demand expansion due to the restriction on use of antibiotics in pork produced for some buyers. Welfare of consumers who purchase pork products from these buyers is, accordingly, reduced. The reduction in consumer surplus to these consumers ranges from $419 million for $\delta = 0.1$ and $\theta = 0.5$ to $975 million for $\delta = 0.3$ and $\theta = 0.3$. These results apply to the setting where intermediary buyers are demanding AF pork in response to pressure from activists and/or the wish to burnish their image as responsible corporate citizens, not from any impetus from pork consumers. If pork consumers are aware of and value the fact that the pork products they are purchasing in these settings come from AF hogs, there would be a corresponding surplus gain to offset the impact from higher prices.

Consumer prices are slightly lower (from $0.22 to $1.59 per cwt. carcass weight) for pork products sold in the conventional market (due to the overall reduction in pork sales), so those consumers obtain a small increase in consumer surplus, ranging from $46 million for $\delta = 0.1$ and $\theta = 0.5$ to $328 million for $\delta = 0.3$ and $\theta = 0.3$. The net impact on consumers, found by aggregating the changes for consumers of restricted pork products and conventional pork products, is negative and ranges from a net loss of surplus annually of $373 million to $647 million. These net amounts embed a transfer of economic welfare from consumers of restricted pork products to consumers of conventional pork products.

Subcases with Demand Growth

As noted, there is a paucity of objective evidence as to how imposing production restrictions will impact demand for buyers imposing them. To get a rough sense of how demand-side impacts may interact with the assured cost- and supply-side impacts, we utilized the market shares of organic production for key animal products: pork (0.02%), eggs (1.47%), and milk (2.7%) as suggestive of possible demand increases that could occur in the AF segment of the pork market. In all cases we fixed values for δ at its midrange value, $\delta = 0.2$, in conducting these simulations.

Results for subcase 2 (demand growth in the AF sector that is not offset by demand reduction in the N sector) are presented in tables 3 and 4. The 0.02% demand growth associated with the organic share for pork is, of course, inconsequential. Price and production impacts are virtually unchanged from the no-demand-growth case provided for comparison in the top portion of each table. The case is worth including only because it reflects market data for a key enhanced pork-product characteristic, organically produced.

The higher demand growth rates do have a noticeable impact on production and prices, but even the highest demand growth rate simulated for the AF sector, the 2.7% associated with the organic milk market share, is not sufficient to offset fully the reduction in pork production due to higher costs and prices associated with producing AF pork. Thus, total pork sales are lower and the conventional (N) hog price is lower than the baseline case where only conventional pork is produced even under the 2.7% demand-growth scenario. Because hog producers can substitute freely between producing N and AF hogs in this model, the AF producers are exactly compensated for their higher costs relative to N producers, so all hog producers receive lower net revenue under even the high demand-growth scenario. In order for farm price to not fall for conventional hog producers as a result of the introduction of the AF market segment, AF demand must increase by 12.5% (and not impact demand in the N market) for the case when $\delta = 0.2$ and $\theta = 0.3$, well above the range of values simulated here and above the range which seems realistic given the limited information available.

Results in tables 5 and 6 for subcase 3, offsetting demand effects, offer few surprises. If demand growth in the AF segment of the market comes at the expense of the conventional segment, then results are very similar to the no-demand-growth baseline case. Even though AF demand grows at the expense of conventional demand in subcase 3, retail prices in the AF segment do not increase relative to prices in the conventional segment because hog production can shift seamlessly between AF and N production by incurring the higher costs associated with AF production. Thus, the main effect of growth in demand in the AF segment of the market at the expense of the conventional segment is on the portion of total hog production that is raised without use of antibiotics for growth promotion and disease prevention. Total pork production and consumption, retail prices, and farm prices are unaffected by this type of "zero sum" reallocation of demand.

Conclusion

The pork industry, from the farm to the final consumer, faces many challenges including perceptions of consumers of pork products, key downstream intermediary buyers, society at large, and policy makers about social, environmental and economic issues confronting the industry. Several of these issues relate to specifics of how hogs are raised. This study has considered the emerging scenario wherein key downstream buyers of pork products impose restrictive production requirements on their suppliers.

We focused specifically on the economic issues associated with such restrictions for the U.S. pork industry and and constructed a simulation model of the industry designed to evaluate the likely price, quantity, and welfare impacts of such restrictions. The model was applied specifically to a ban by some buyers on the use of antibiotics for growth promotion and disease prevention in their pork purchases, a practice for which we had reasonably good data on the production and processing cost impacts.

On-farm costs increase from restrictions on such uses of such antibiotics due to higher mortality, higher disease incidence and costly treatment, greater space requirements and associated capital costs, and lower feed efficiency. Processors' costs also rise due to segregation, traceability, and certification requirements. We showed that two key additional parameters have an important effect on results. The first is the share of the pork in the market that is subject to the restriction. The second is the proportion of the pork from each hog raised under the restriction that is sold in the restricted market.

In all cases simulated, buyers in the restricted market faced considerably higher prices for pork products. These higher prices, ceteris paribus, caused lower consumer and hog-producer welfare and reduced the aggregate quantity of pork demanded and sold in the market.

Demand expansion has the potential to offset or even to dominate these welfare impacts due to the cost increases associated with producing pork without the use of antibiotics for growth promotion or disease prevention. We discussed several different ways in which the demand side of the market might be affected. However, even under the most optimistic demand-growth scenario we simulated, farm price for conventionally produced pork fell, meaning that hog producers' surplus was diminished due to imposition of the restrictions. Because farmers can switch between production of hogs with restricted uses of antibiotics and conventionally raised hogs, those farmers that raise hogs with restricted uses of antibiotics are exactly compensated in equilibrium for their higher costs and are no better off than their counterparts in the conventional segment of the market.

Buyers imposing or considering imposing restrictive production practices for the products they procure are all multiproduct sellers, and, even if the requirements cause these sellers to lose revenue for sales of the restricted products due to higher costs and prices, they may proceed with such restrictions because they increase sales of other products if the restrictions on their procurement enhances the seller's corporate image and increases consumers' demands for its other products. Thus, it may be profitable for such buyers to impose the restrictive production practices even though producers and processors in the industry lose revenue and profits as a consequence.

Table 1. Subcase 1 Retail and Farm Price Impacts When Some Buyers Require AF Pork Products

θ	Retail Price AF ($/cwt. CW)	Retail Price Conventional ($/cwt. CW)	% Δ Retail Price Conventional	% Premium of AF Over Conventional	Farm Value for Conventional Pork ($/ cwt. CW)	% Δ Farm Value for Conventional Pork	Farm Value for AF Pork ($/cwt. CW)	% Premium for AF Pork
				Baseline (δ=0)				
1		250.64			88.02			
				Low AF Share (δ=0.10)				
0.3	296.91	250.11	-0.21%	18.71%	87.49	-0.60%	97.99	12.00%
0.4	278.85	250.32	-0.13	11.40	87.70	-0.37	95.57	8.98
0.5	270.10	250.42	-0.09	7.86	87.80	-0.25	94.10	7.18
				Medium AF Share (δ=0.20)				
0.3	296.38	249.58	-0.42	18.75	86.96	-1.21	97.46	12.07
0.4	278.53	249.99	-0.26	11.41	87.37	-0.74	95.25	9.01
0.5	269.87	250.19	-0.18	7.87	87.57	-0.51	93.87	7.19
				High AF Share (δ=0.30)				
0.3	295.84	249.05	-0.64	18.79	86.43	-1.81	96.93	12.15
0.4	278.20	249.67	-0.39	11.43	87.05	-1.10	94.92	9.05
0.5	269.65	249.97	-0.27	7.87	87.35	-0.76	93.65	7.21

Note: All quantities and prices are computed on a carcass weight (CW) basis.

Table 2. Subcase 1 Production and Consumption Impacts When Some Buyers Require AF Pork Products

θ	Production of AF Pork (cwt. CW)	Production of Conventional Pork (cwt. CW)	% Δ Production of Conventional Pork	Domestic Consumption (cwt. CW)	% Δ Domestic Consumption	Total Pork Production (cwt. CW)	% Δ Total Pork Production
			Baseline (δ=0)				
1		229,392,611		185,533,201		229,392,611	
			Low AF Share (δ=0.10)				
0.3	67,088,651	159,781,857	-30.35%	183,011,098	-1.36%	226,870,508	-1.10%
0.4	53,060,458	174,794,252	-23.80	183,995,299	-0.83	227,854,709	-0.67
0.5	43,513,042	184,819,012	-19.43	184,472,644	-0.57	228,332,054	-0.46
			Medium AF Share (δ=0.20)				
0.3	134,392,534	89,955,872	-60.79	180,488,995	-2.72	224,348,405	-2.20
0.4	106,219,346	120,097,461	-47.65	182,457,398	-1.66	226,316,808	-1.34
0.5	87,080,387	140,191,110	-38.89	183,412,087	-1.14	227,271,497	-0.92
			High AF Share (δ=0.30)				
0.3	201,911,648	19,914,654	-91.32	177,966,892	-4.08	221,826,302	-3.30
0.4	159,476,667	65,302,239	-71.53	180,919,496	-2.49	224,778,906	-2.01
0.5	130,702,036	95,508,904	-58.36	182,351,530	-1.71	226,210,940	-1.39

Note: All quantities and prices are computed on a carcass weight (CW) basis.

Table 3. Subcase 2 AF Demand Growth: Retail and Farm Price Impacts When Some Buyers Require AF Pork Products

θ	Retail Price AF ($/cwt. CW)	Retail Price Conventional ($/cwt. CW)	% Δ Retail Price Conventional	% Premium of AF Over Conventional	Farm Value for Conventional Pork ($/ cwt. CW)	% Δ Farm Value for Conventional Pork	Farm Value for AF Pork ($/cwt. CW)	% Premium for AF Pork
				Baseline (δ=0)				
1		250.64			88.02			
				No AF Demand Growth				
0.3	296.38	249.58	-0.42	18.75	86.96	-1.21	97.46	12.07
0.4	278.53	249.99	-0.26	11.41	87.37	-0.74	95.25	9.01
0.5	269.87	250.19	-0.18	7.87	87.57	-0.51	93.87	7.19
				Low AF Demand Growth (0.02%)				
0.3	296.38	249.58	-0.42	18.75	86.96	-1.20	97.46	12.07
0.4	278.53	249.99	-0.26	11.41	87.37	-0.73	95.25	9.01
0.5	269.87	250.20	-0.18	7.87	87.57	-0.51	93.87	7.19
				Medium AF Demand Growth (1.47%)				
0.3	296.49	249.69	-0.38	18.74	87.07	-1.08	97.57	12.06
0.4	278.65	250.11	-0.21	11.41	87.49	-0.60	95.37	9.00
0.5	269.99	250.31	-0.13	7.86	87.69	-0.37	93.99	7.18
				High AF Demand Growth (2.7%)				
0.3	296.58	249.79	-0.34	18.74	87.17	-0.97	97.67	12.05
0.4	278.75	250.21	-0.17	11.40	87.59	-0.49	95.47	8.99
0.5	270.10	250.42	-0.09	7.86	87.80	-0.25	94.10	7.18

Note: All quantities and prices are computed on a carcass weight (CW) basis.

Table 4. Subcase 2 AF Demand Growth: Production and Consumption Impacts When Some Buyers Require AF Pork Products

θ	Production of AF Pork (cwt. CW)	Production of Conventional Pork (cwt. CW)	% Δ Production of Conventional Pork	Domestic Consumption (cwt. CW)	% Δ Domestic Consumption	Total Pork Production (cwt. CW)	% Δ Total Pork Production
			Baseline (δ=0)				
1		229,392,611		185,533,201		229,392,611	
			No AF Demand Growth				
0.3	134,392,534	89,955,872	-60.79	180,488,995	-2.72	224,348,405	-2.20
0.4	106,219,346	120,097,461	-47.65	182,457,398	-1.66	226,316,808	-1.34
0.5	87,080,387	140,191,110	-38.89	183,412,087	-1.14	227,271,497	-0.92
			Low AF Demand Growth (0.02%)				
0.3	134,418,807	89,936,748	-60.79	180,496,145	-2.71	224,355,555	-2.20
0.4	106,240,112	120,084,230	-47.65	182,464,932	-1.65	226,324,342	-1.34
0.5	87,097,411	140,181,807	-38.89	183,419,808	-1.14	227,279,218	-0.92
			Medium AF Demand Growth (1.47%)				
0.3	136,351,408	88,530,070	-61.41	181,022,068	-2.43	224,881,478	-1.97
0.4	107,767,575	119,110,996	-48.08	183,019,161	-1.36	226,878,571	-1.10
0.5	88,349,650	139,497,525	-39.19	183,987,766	-0.83	227,847,176	-0.67
			High AF Demand Growth (2.7%)				
0.3	138,034,888	87,304,719	-61.94	181,480,197	-2.18	225,339,607	-1.77
0.4	109,098,141	118,263,216	-48.45	183,501,948	-1.09	227,361,358	-0.89
0.5	89,440,471	138,901,450	-39.45	184,482,511	-0.57	228,341,921	-0.46

Note: All quantities and prices are computed on a carcass weight (CW) basis.

Table 5. Subcase 3 Offsetting Demand Effects: Retail and Farm Price Impacts When Some Buyers Require AF Pork Products

θ	Retail Price AF ($/cwt. CW)	Retail Price Conventional ($/cwt. CW)	% Δ Retail Price Conventional	% Premium of AF Over Conventional	Farm Value for Conventional Pork ($/ cwt. CW)	% Δ Farm Value for Conventional Pork	Farm Value for AF Pork ($/cwt. CW)	% Premium for AF Pork
				Baseline (δ=0)				
1		250.64			88.02			
				No AF Demand Growth				
0.3	296.38	249.58	-0.42	18.75	86.96	-1.21	97.46	12.07
0.4	278.53	249.99	-0.26	11.41	87.37	-0.74	95.25	9.01
0.5	269.87	250.19	-0.18	7.87	87.57	-0.51	93.87	7.19
				Low AF Demand Growth (0.02%)				
0.3	296.38	249.58	-0.42	18.75	86.96	-1.21	97.46	12.07
0.4	278.53	249.99	-0.26	11.41	87.37	-0.74	95.25	9.01
0.5	269.87	250.19	-0.18	7.87	87.57	-0.51	93.87	7.19
				Medium AF Demand Growth (1.47%)				
0.3	296.36	249.56	-0.43	18.75	86.94	-1.22	97.44	12.08
0.4	278.52	249.99	-0.26	11.42	87.36	-0.74	95.24	9.01
0.5	269.87	250.19	-0.18	7.87	87.57	-0.51	93.87	7.19
				High AF Demand Growth (2.7%)				
0.3	296.35	249.56	-0.43	18.75	86.94	-1.23	97.44	12.08
0.4	278.52	249.98	-0.26	11.42	87.36	-0.75	95.24	9.01
0.5	269.87	250.19	-0.18	7.87	87.57	-0.51	93.87	7.19

Note: All quantities and prices are computed on a carcass weight (CW) basis.

Table 6. Subcase 3 Offsetting Demand Effects: Production and Consumption Impacts When Some Buyers Require AF Pork Products

θ	Production of AF Pork (cwt. CW)	Production of Conventional Pork (cwt. CW)	% Δ Production of Conventional Pork	Domestic Consumption (cwt. CW)	% Δ Domestic Consumption	Total Pork Production (cwt. CW)	% Δ Total Pork Production
				Baseline (δ=0)			
1		229,392,611		185,533,201		229,392,611	
				No AF Demand Growth			
0.3	134,392,534	89,955,872	-60.79	180,488,995	-2.72	224,348,405	-2.20
0.4	106,219,346	120,097,461	-47.65	182,457,398	-1.66	226,316,808	-1.34
0.5	87,080,387	140,191,110	-38.89	183,412,087	-1.14	227,271,497	-0.92
				Low AF Demand Growth (0.02%)			
0.3	134,419,503	89,927,895	-60.80	180,487,988	-2.72	224,347,398	-2.20
0.4	106,240,634	120,075,561	-47.66	182,456,785	-1.66	226,316,195	-1.34
0.5	87,097,828	140,173,246	-38.89	183,411,665	-1.14	227,271,075	-0.92
				Medium AF Demand Growth (1.47%)			
0.3	136,403,131	87,881,159	-61.69	180,424,880	-2.75	224,284,290	-2.23
0.4	107,806,324	118,475,723	-48.35	182,422,637	-1.68	226,282,047	-1.36
0.5	88,380,633	138,870,341	-39.46	183,391,564	-1.15	227,250,974	-0.93
				High AF Demand Growth (2.7%)			
0.3	138,130,771	86,115,605	-62.46	180,386,967	-2.77	224,246,377	-2.24
0.4	109,169,973	117,099,385	-48.95	182,409,948	-1.68	226,269,358	-1.36
0.5	89,497,905	137,752,614	-39.95	183,391,108	-1.15	227,250,518	-0.93

Note: All quantities and prices are computed on a carcass weight (CW) basis.

References

Aubrey A. (2012) "Antibiotic-Free Meat Business Is Booming, Thanks To Chipotle." Available at: http://www.npr.org/blogs/thesalt/2012/05/31/154084442/antibiotic-free-meat-business-is-booming-thanks-to-chipotle. May 31. Accessed May 8, 2013.

Andersen L.M. (2011) "Animal welfare and eggs–cheap talk or money on the counter?" *Journal of Agricultural Economics* 62:565–584.

Brorsen, B., Wade, T. Lehenbauer, D. Li, and J. Connor. (2002) "Economic Impacts of Banning Subtherapeutic Use of Antibiotics in Swine Production." *Journal of Agricultural and Applied Economics.* 34:489–500.

Buhr, B. (2005) "U.S. Pork, Beef, and Chicken Sector Economic Simulation Model with International Trade and Probability-Based Sensitivity Analysis." Report prepared for the National Pork Board.

Buhr, B. (2010) "Economic impact of transitioning from gestation stalls to group pen housing in the U.S. pork industry." (Staff paper P10-4) St. Paul, MN: University of Minnesota, Department of Applied Economics.

Chang J., J. Lusk, and F. Norwood. (2010) "The price of happy hens: A hedonic analysis of retail egg prices." *Journal of Agricultural and Resource Economics* 35:406–423.

Cheeseman G. (2012) "Safeway Exceeds Cage-Free Eggs Goal." Available at: http://www.triplepundit.com/2012/12/safeway-exceeds-cage-free-eggs-goal/. December 26. Accessed May 8, 2013.

Chilton S., D. Burgess, and W. Hutchinson. (2006) "The relative value of farm animal welfare." *Ecological Economics* 59:353–363.

Cromwell, G. (2002) "Why and how antibiotics are used in swine production." *Animal Biotechnology* 13:7-27.

Glass C., W. Hutchinson, and V. Beattie. (2005) "Measuring the value to the public of pig welfare improvements: a contingent valuation approach." *Animal Welfare* 14:61–69.

Gracia A., M. Loureiro, and R. Nayga Jr. (2011) "Valuing an EU animal welfare label using experimental auctions." *Agricultural Economics* 42:669–677.

Hayes, D. and H. Jensen. (2003) "Lessons from the Danish Ban on Feed-Grade Antibiotics." Center for Agricultural and Rural Development, Iowa State University, Briefing Paper 03-BP 41.

Hayes, D., H. Jensen, L. Backstrom, and J. Fabiosa. (2001) "Economic impact of a ban on the use of over the counter antibiotics in U.S. swine rations." *International Food and Agribusiness Management Review* 4:81–97.

Hobbs J. (2003) "Traceability and country of origin labeling." In Policy Dispute Information Consortium 9th Agricultural and Food Policy Information Workshop, Montreal.

Informa Economics. (2010) "Update of Cost Assessments for Country-of-Origin Labeling—Beef & Pork (2009)."

Lagerkvist, C., F. Carlsson, and D. Viske. (2006) "Swedish Consumer Preferences for Animal Welfare and Biotech: A Choice Experiment." *AgBioForum* 9:51–58.

Larson, B., and J. Kliebenstein. (2003) "Cost of Pork Production with Nonsubtherapeutic Use of Antibiotics," Swine Research Report, ASL-R1820, Iowa State University, January.

Lemieux, C. and M. Wohlgenant. (1989) "'Ex Ante' Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin." *American Journal of Agricultural Economics* 71: 903-914.

Liljenstolpe C. (2008) "Evaluating animal welfare with choice experiments: An application to Swedish pig production." *Agribusiness* 24:67–84.

Okrent, A. and J. Alston. (2011) "Demand for Food in the United States. A Review of Literature, Evaluation of Previous Estimates, and Presentation of New Estimates." Giannini Foundation Monograph 48.

Olynk N., G. Tonsor, and C. Wolf. (2010) "Consumer willingness to pay for livestock credence attribute claim verification." *Journal of Agricultural and Resource Economics* 35:261–280.

Sumner D., H. Gow, D. Hayes, W. Matthews, B. Norwood, J. Rosen-Molina, and W. Thurman. (2011) "Economic and market issues on the sustainability of egg production in the United States: Analysis of alternative production systems." *Poultry Science* 90:241–250.

The Humane Society of the United States. (2013) "Progress for Egg-Laying Hens." Available at: http://www.humanesociety.org/issues/confinement_farm/timelines/eggs_timeline.html. April 26. Accessed May 8, 2013.

Tonsor G. and C. Wolf. (2011) "On mandatory labeling of animal welfare attributes." *Food Policy* 36:430–437.

Tonsor G., N. Olynk, and C. Wolf. (2009) "Consumer preferences for animal welfare attributes: The case of gestation crates." *Journal of Agricultural and Applied Economics* 41:713–730.

U.S. Department of Agriculture, Economic Research Service (2010) "Certified Organic and Total U.S. Acreage, Selected Crops and Livestock, 1995-2008.